4.2 Access to fresh water

Significant ideas

The supplies of freshwater resources are inequitably available and unevenly distributed and this can lead to conflict and concerns over water security.

Freshwater resources can be sustainably managed using a variety of different approaches.

Big questions

As you read this section, consider the following big questions:

- What strengths and weaknesses of the systems approach and the use of models have been revealed through this topic?
- To what extent have the solutions emerging from this topic been directed at *preventing* environmental impacts, *limiting* the extent of the environmental impacts, or *restoring* systems in which environmental impacts have already occurred?
- How are the issues addressed in this topic of relevance to sustainability or sustainable development?
- In what ways might the solutions explored in this topic alter your predictions for the state of human societies and the biosphere some decades from now?

Knowledge and understanding

- Access to an adequate supply of fresh water varies widely.
- Climate change may disrupt rainfall patterns and further affect this access.
- As population, irrigation, and industrialization increase, the demand for fresh water increases.
- Freshwater supplies may become limited through contamination and unsustainable abstraction.
- Water supplies can be enhanced through reservoirs, redistribution, desalination, artificial recharge of aquifers, and rainwater harvesting schemes. Water conservation (including grey-water recycling) can help to reduce demand but often requires a change in attitude by water users.
- The scarcity of water resources can lead to conflict between human populations particularly where sources are shared.

Access to fresh water

Access to an adequate supply of fresh water varies widely.

Human populations require water for home use (drinking, washing, and cooking), agriculture (irrigation and livestock), industry (manufacturing and mining), and hydroelectric power. Given the scarcity of freshwater resources, the pressure put on them is great and likely to increase in the future in parts of the world (Figure 4.8). Without sustainable use it is likely that humans will face many problems. Already there are a billion people who live without clean drinking water, and 2.6 billion who lack adequate sanitation.

The world's available freshwater supply is not distributed evenly around the globe, either seasonally, or from year to year. About three-quarters of annual rainfall occurs in areas containing less than a third of the world's population, whereas two-thirds of

the world's population live in the areas receiving only a quarter of the world's annual rainfall. For instance, about 20 per cent of the global average run-off each year is accounted for by the Amazon Basin, a vast region with fewer than 10 million people. Similarly, the Congo Basin accounts for about 30 per cent of the Africa's annual run-off, but has less than 10 per cent of its population.

African women using a river for washing clothes

As Figure 4.8 suggests, the availability of fresh water is likely to become more stressed in the future. This may be the result, in part, of climate change, whereby rising temperatures lead to melting glaciers and increased evaporation. Unequal access to water may cause a conflict between those who have an abundance of water and those who do not (case study, page 228).

Every year, more people die from poor quality water than from all forms of violence, including war.

Climate change may disrupt rainfall patterns and further affect access to fresh water.

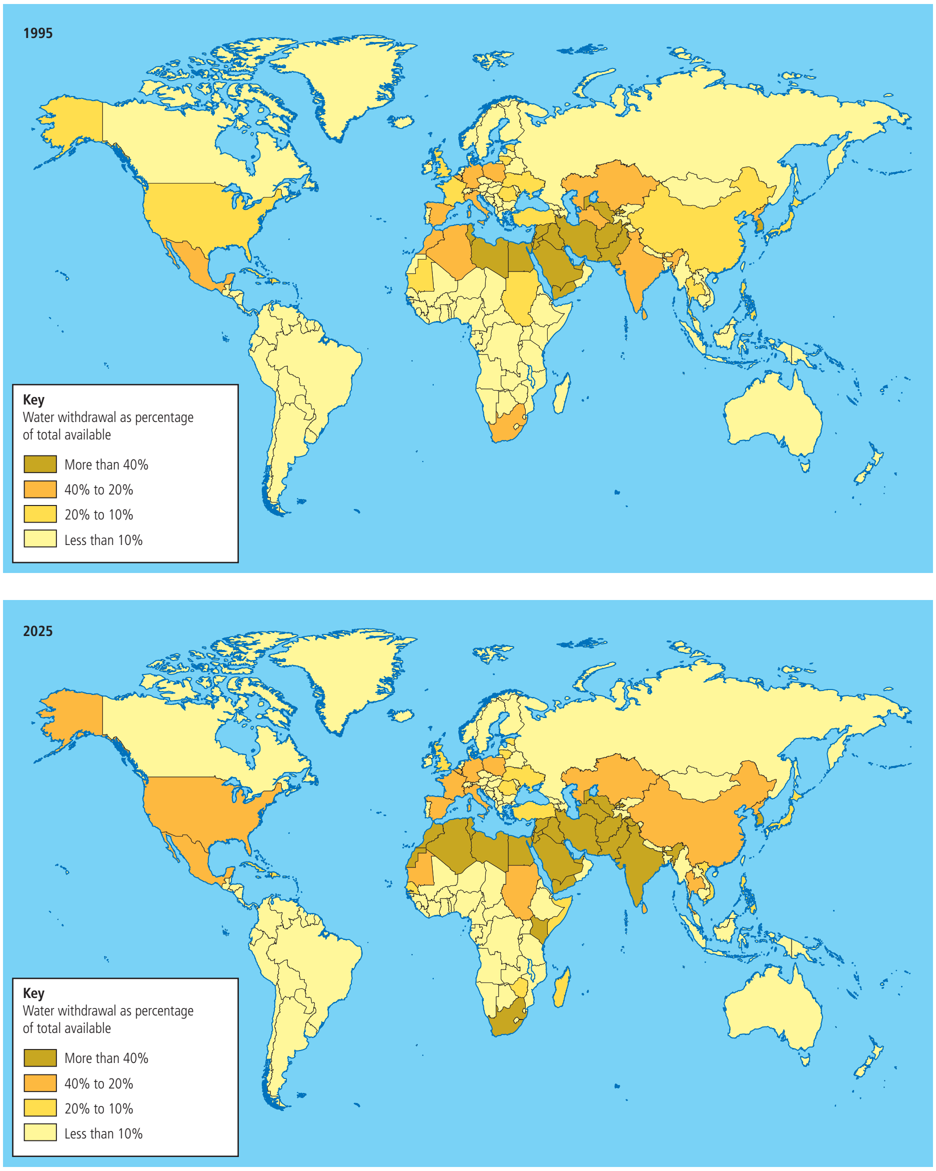


Figure 4.8 Water stress, 1995 and 2025

Case study

The price of water for the world's poor

In some cases, the poor actually pay more for their water than the rich. For example, in Port-au-Prince, Haiti, surveys have shown that households connected to the water system typically paid around US$1.00 per cubic metre, while unconnected customers forced to purchase water from mobile vendors paid from US$5.50 to a staggering US$16.50 per cubic metre.

Urban residents in the United States typically pay US$0.40–0.80 per cubic metre for municipal water of excellent quality. In Lima, Peru, poor families on the edge of the city pay vendors roughly US$3.00 per cubic metre, 20 times the price for families connected to the city system.

Residents of Jakarta, Indonesia, purchase water at US$0.09–0.50 per cubic metre from the municipal water company, US$1.80 from tanker trucks, and US$1.50–2.50 from private vendors – as much as 50 times more than residents connected to the city system. Jakarta's water supply and disposal systems were designed for 500 000 people, but today are struggling with more than 15 million.

The city suffers continuous water shortages, and less than 25 per cent of the population has direct access to water supply systems. The water level in what was previously an artesian aquifer is now generally below sea level – in some places 30 m below. Saltwater intrusion and pollution have largely ruined this as a source of drinking water.

TOK

A child collecting water from a well

Aid agencies frequently make use of emotive advertisements around water and food security issues.

Look at the photograph opposite and consider these questions.

1 Why is a child collecting water? Why not an adult?
2 Why is there such a large 'hole' in the ground?
3 Is this likely to be a rural or urban environment? What is the evidence for your answer?
4 Why is water scarce in this environment?
5 What impact could water scarcity have on children's education?
6 How could their lives be affected by water shortages?
7 To what extent can emotion be used to manipulate knowledge and actions?

As population, irrigation, and industrialization increase, the demand for fresh water increases.

Changes in demand and supply

Unsustainable demands

The demand for water has continued to grow throughout the industrial period, and is still expanding in both MEDCs and LEDCs. Increased demand in LEDCs is due to expanding populations, rising standards of living, changing agricultural practice and expanding (often heavy) industry. In MEDCs, people require more and more water as they wash more frequently, water their gardens, and wash their cars. Overall, it is a general increase in water use per person that is making demand heavier. Water is a finite resource and countries are reaching their resource availability limits – existing water resources therefore need to be managed and controlled more carefully, and new water resources found.

Water scarcity may become more widespread and have an increasing impact in the future – declining soil moisture has a very important impact on plant productivity.

As world population and industrial output have increased, the use of water has accelerated, and this is projected to continue. By 2025, global availability of fresh water may drop to an estimated 5100 m^3 per person per year, a decrease of 25 per cent on the 2000 figure. Rapid urbanization results in increasing numbers of people living in urban shanty towns where it is extremely difficult to provide an adequate supply of clean water or sanitation.

Freshwater supplies may become limited through contamination and unsustainable extraction.

Irrigation, industrialization, and population increase all make demands on the supply of fresh water. Global warming may disrupt rainfall patterns and water supplies. The hydrological cycle supplies humans with fresh water but we are withdrawing water from underground aquifers and degrading it with wastes at a greater rate than it can be replenished.

As water quality declines in some regions, more than half of native freshwater fish species and nearly one-third of the amphibians are at risk of extinction.

CONCEPTS: Environmental value systems

Technocentrists would argue that solutions can be found to sustain human populations and overcome unsustainable use of water resources. The cases outlined in this section demonstrate the serious situations many areas of the world face regarding their water resources and that how, even with technological progress, water supply remains of critical concern.

While some uses of river resources can be unsustainable (e.g. the siltation caused by dams), rivers can generally be replenished over a short period of time. Unsustainable use of fresh water largely concerns the overuse of aquifers. These non-renewable sources of water cannot be replenished at a fast-enough rates to make current usage sustainable. The USA is one of the world's largest agricultural producers. In certain areas, irrigation has been depleting groundwater resources beyond natural recharge rates for several years. For example, the High Plains (Ogallala) aquifer irrigates more than 20 per cent of USA cropland It is close to depletion in parts of Kansas because the water level has fallen so much (Figure 4.9). In some regions, water depletion now poses a serious threat to the sustainability of the agricultural and rural economy.

Water supplies can be enhanced through reservoirs, redistribution, desalination, artificial recharge of aquifers, and rainwater harvesting schemes. Water conservation (including grey-water recycling) can help to reduce demand but often requires a change in attitude by the water users.

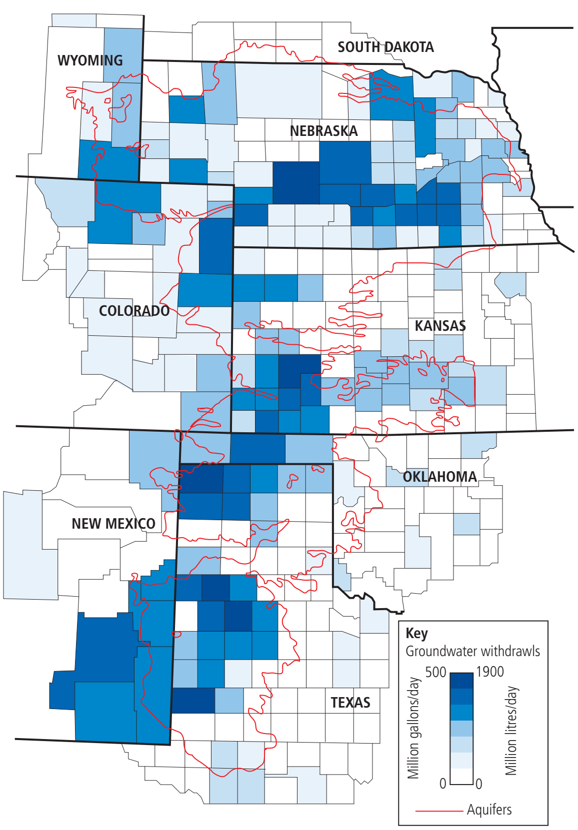


Figure 4.9 Impact of water use on High Plains aquifer

Projections over the next decade suggest that demand for water from irrigators will continue to rise, notably in countries where irrigated farming provides the major share of agricultural production (e.g. Australia, Mexico, Spain, and the USA). Groundwater pumping in Saudi Arabia exceeds replenishment by five times. This will lead to stiffer competition for water among other users (e.g. domestic use). Pressure on irrigated farming in many drier and semi-arid areas is being caused by the growing incidence and severity of droughts over the past decade, perhaps related to the impact of climate change. Demand for water will increase as a result, in part, of more people and greater demand for more food. Moreover, some of the water is being contaminated through excessive use of fertilizers and chemical waste dumping. Consequently, there will be further increased pressure of water resources.

Sustainably managing water resources

Water resources can be managed sustainably if individuals and communities make changes locally *and* this is supported by national government. Water usage needs to be coordinated within natural processes, and management strategy should ensure that non-renewable sources of fresh water (e.g. aquifers) are not used at an unsustainable rate. Use can be reduced by self-imposed restraint; for example, using water only when it is essential, not causing waste, and reusing supplies such as bath water. Education campaigns can increase local awareness of issues and encourage water conservation. There are many opportunities to increase fresh water supplies:

You must be able to evaluate the strategies that can be used to meet increasing demand for fresh water. You must give their strengths and their weaknesses

- retain water in reservoirs for use in dry seasons
- redistribute water from wetter areas to drier areas (e.g. from southern China to northern China)
- desalinate sea water (but this is expensive)
- water conservation (e.g. recycle grey-water – water that has already been used so is not fit for drinking but could be used for other purposes).

Water harvesting in Antigua – water flows over the concrete surface and is directed into a collection tank.

Water harvesting refers to making use of available water before it drains away or is evaporated. Water can be harvested in many ways. The main ones are:

- extraction from rivers and lakes (e.g. by primitive forms of irrigation such as the shaduf and Archimedes screw) – aided by gravity
- trapping behind dams and banks (bunds)
- pumping from aquifers (water-bearing rocks)
- desalinating saltwater to produce fresh water.

These can be achieved with either high technology or low technology methods. Efficient use or storage of water can also be achieved in many ways, for example:

- irrigation of individual plants rather than of whole fields
- covering expanses of water with plastic or chemicals to reduce evaporation
- storage of water underground in gravel-filled reservoirs (to reduce evaporation losses).

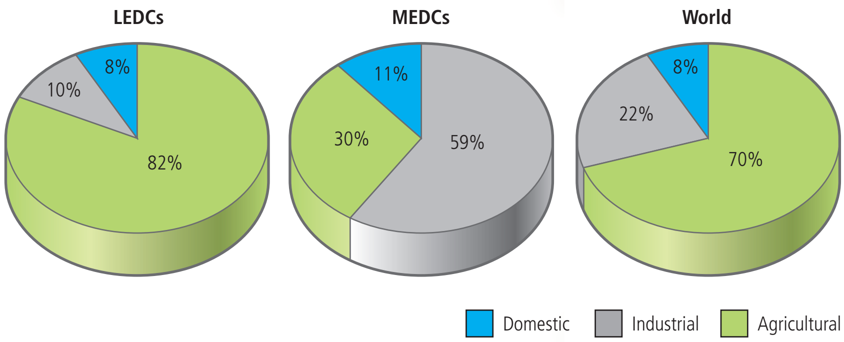
Sustainable use of water in cities and populated areas could be achieved by:

- making new buildings more water-efficient (e.g. recycling rainwater for sanitation and showers)
- offsetting new demand by fitting homes and other buildings with more water-efficient devices and appliances (e.g. dishwashers and toilets)
- expanding metering to encourage households to use water more efficiently.

In rural areas, solutions for sustainable water use could include selecting drought-resistant crops to reduce the need for irrigation (which uses up fresh water – much of it wasted through evaporation – and can cause soil degradation). Contamination of water supplies through fertilizers and pesticides can be addressed by reducing their use: organic fertilizers cause less pollution and biocontrol (i.e. natural predators of pests) can be used to reduce crop pests. Industries can be forced to remove pollutants from their wastewater through legislation.

The response of individuals and governments to make their use of fresh water more sustainable depend on the level of development of their country. Competing demands on fresh water vary between countries. Domestic water consumption is the minority water use in all countries, so the biggest impacts in terms of sustainable water use will be within the agricultural sector in LEDCs, and within the industrial sector in MEDCs (Figure 4.10).

Figure 4.10 Water use in LEDCs and MEDCs



CONCEPTS: Environmental value systems

Environmental value systems determine water usage: ecocentrist managers plan to use these resources sustainably (i.e. by not diminishing them to such a degree as to make them non-replenishable). How would this differ from a technocentrist approach?

There is a long list of measures that can increase agricultural water productivity (Table 4.10). Drip irrigation is the method with the most untapped potential for farmers. Drip irrigation is a system of plastic tubes installed at or just below the soil surface to deliver water to individual plants. The water, which can be enhanced with fertilizer, is delivered to the roots of plants, so that there is very little lost to evaporation. Drip irrigation can achieve as high as 95 per cent efficiency compared with 50–70 per cent for conventional flood systems. In surveys across the USA, Spain, Jordan, Israel, and India, drip irrigation has been shown to cut water use by between 30 per cent and 70 per cent and to increase crop yields by 20–90 per cent, even leading to a doubling of productivity. Nevertheless, drip irrigation accounts for only 1 per cent of all irrigated land worldwide. Low-cost irrigation methods are summarized in Table 4.11.

Table 4.10 Options for improving irrigation water productivity

Category	Measures
technical	• land levelling to apply water more uniformly • efficient sprinklers to apply water more uniformly • drip irrigation to cut evaporation and other water losses and to increase crop yields
managerial	• applying water when most crucial to a crop's yield • better maintenance of canals and equipment
institutional	• establishing water user organizations for better involvement of farmers and collection of fees • reducing irrigation subsidies and/or introducing conservation-orientated pricing
agronomic	• selecting crop varieties with high yields per litre of transpired water • better matching of crops to climate conditions and the quality of water available • selecting drought-tolerant crops where water is scarce or unreliable

Table 4.11 Low-cost irrigation methods for small farmers

Technology or method	General conditions where appropriate	Examples
cultivating wetlands, delta lands, valley bottoms	seasonally waterlogged floodplains or wetlands	• Niger and Senegal river valleys • fdambos of Zambia and Zimbabwe
Archimedean screw, shaduf or beam and bucket, hand pump	very small (less than 0.5 ha) farm plots underlain by shallow groundwater	• eastern India • Bangladesh • parts of South East Asia
Persian wheel, bullocks and other animal-powered pumps, low-cost mechanical pumps	similar to those above, but where the average size of farm plots is roughly 0.5–2.0 ha	• as above, plus: • parts of North Africa and Near East
various forms of low-cost micro-irrigation (including bucket kits, drip systems, micro-sprinklers)	areas with perennial but scarce water supply; hilly, sloping or terraced farmlands	• north-west, central and southern India • Nepal • central Asia, China, near East
tanks, check dams, terracing	semi-arid and/or drought-prone areas	• much of semi-arid South Asia

Groundwater pollution from fertilizer run-off is causing depletion of the stock of fresh water. Over a fifth of groundwater monitoring sites in agricultural areas of Denmark, the Netherlands, and the USA have recorded nitrate levels that exceed drinking water standards: a particular concern where groundwater provides the main source of drinking water for both people and livestock. The situation is likely to deteriorate as phosphates (also widely used in agriculture) can take many years to seep into the groundwater from the soil.

Over-exploitation of water resources by agriculture has damaged some aquatic ecosystems, and has harmed recreational and commercial fishing.

Conflict arising from shared water resources

As populations grow, greater demands are made on water resources. Water resources are now becoming a limiting factor in many societies, and the availability of water for drinking, industry and agriculture needs to be considered. Many societies are now dependant primarily on groundwater, which is non-renewable. As societies develop, water needs increase. The increased demand for fresh water can lead to inequity of usage and political consequences. When water supplies fail, populations will be forced to take drastic steps, such as mass migration. Water shortages may also lead to civil unrest and wars.

The scarcity of water resources can lead to conflict between human populations particularly where sources are shared.

You should be able to discuss, with reference to a case study, how shared freshwater resources have given rise to international conflict.

Case study

Water and conflict in the Nile Basin

Country	Population in millions	Growth rate / %	PPP / US$	Water footprint / $m^3\ yr^{-1}$
Burundi	10	3.3	600	719
D R Congo	77	2.5	400	552
Egypt	86	1.8	6600	1341
Eritrea	6	2.3	1200	1089
Ethiopia	96	2.9	1300	1167
Kenya	45	2.1	1800	1101
Rwanda	12	2.6	1500	821
Sudan	35	1.8	2600	1736
South Sudan	11	4.1	1400	1736*
Tanzania	49	2.8	1700	1026
Uganda	36	3.2	1500	1079

*No separate reading for South Sudan

Table 4.12 Characteristics of countries in the Nile Basin

The Nile has three main tributaries – the White Nile, the Blue Nile, and the Atbara. The 11 countries in the Nile Basin depend heavily on the river. It is the only major renewable source of water in the region, hence it is vital for water and food security. The Nile basin countries have a total population of over 450 million people. Over 200 million people rely directly on the Nile for their food and water security. The population is expected to double within 25 years – putting immense pressure on the river for water for agriculture, industry and domestic uses.

The Nile's origin is outside the borders of Egypt, but this did not prevent Egypt from getting the lion's share of its waters. A 1929 treaty between Egypt and Britain's East African colonies (Burundi, Kenya, Rwanda, Tanzania, and Uganda) awarded 57 per cent of the waters to Egypt while also requiring other nations to clear with Cairo any major water project on the river. In 1959, Egypt and Sudan signed the Nile Water Agreement in which Egypt was allocated three-quarters of the total water volume (55.5 billion cubic metres) and Sudan one quarter (15.5 billion cubic metres). These two signatories, allocating virtually all of the Nile waters, did not consult Ethiopia, the main source of the river. After the 1959 accord, both Egypt and Sudan built mega-dams to exploit the water for irrigation.

The upstream Nile Basin countries (Figure 4.11) — Burundi, Ethiopia, Kenya, Rwanda, Tanzania, and Uganda — initiated negotiations in 1999 to find an equitable and reasonable way to share the Nile waters. The decade-long negotiations resulted in the 2010 Cooperative Framework Agreement, known as the Entebbe Agreement. The landmark accord, signed by the six upstream countries, was rejected outright by both Egypt and Sudan.

The independence gained by South Sudan in 2011 changed the geopolitical balance of the Nile Basin. It joined the Nile Basin Initiative in 2012. South Sudan controls some 28 per cent of the Nile's flow.

Upstream countries have managed to gain a greater share of the Nile's water resources in recent years. The Nile River Co-operative Framework came into force as international law in 2011 (the Entebbe Agreement). The Entebbe Agreement allows the countries of the Upper Nile Basin to build dams and undertake other water development projects. Current signatories include Ethiopia, Rwanda, Uganda, Kenya, Tanzania, and Burundi.

continued

Figure 4.11 The Nile Basin

Egypt's 'historic rights' to the Nile have led to over-dependency on the river – the Nile accounts for 97 per cent of Egypt's water needs. Few countries are as dependent on a single river as Egypt. Water shortages and the limited amount of arable land in Egypt have led to a heavy reliance on food imports to feed the Egyptian population. Although the agricultural sector uses 80 per cent of Egypt's water, 60 per cent of food has to be imported. Egypt is one of the world's leading grain importers. This makes it extremely vulnerable to global food price increases and shortages in supply.

Until recently, Ethiopia had not bothered to make use of its many rivers. Political instability and poverty in the Nile Basin countries limited their ability to move toward socio-economic development of the Nile. However, in 2011, the country announced plans for the construction of its Great Ethiopian Renaissance Dam (GERD), designed to generate a staggering 6000 megawatts of electricity. The dam is situated on the vast Blue Nile gorge, where the land is unsuitable for agriculture. In 2014, Ethiopia turned down Egypt's demand that it suspend construction of the US$4.2 billion mega-dam on the Nile.

GERD will be the largest dam in Africa. The construction has triggered many protests, especially from Egypt. There is some concern that it could result in the evaporation of 3 billion cubic metres of Nile water (Egypt's Aswan Dam is responsible for the evaporation of 12 billion cubic metres of Nile water annually). Together these dams could lead to much-reduced flows downstream.

The Nile is also threatened by many environmental pressures – climate change, salinization, pollution, land degradation, reduced river flow, and increased likelihood of drought and floods.

Large-scale water developments carry a dual threat – conflict with neighbouring countries, and internal conflict due to the displacement of many communities. Egypt views the building of GERD as a threat to its national security. In the past, Egypt has tended to use military threats in Nile disputes but is unlikely to be able to follow such threats through. Greater co-operation with other Nile Basin countries is likely to be the most feasible way forward for Egypt.

A UN-backed plan suggests using the Nubian Sandstone Aquifer, below the eastern part of the Sahara Desert, for water. Egypt, Sudan, Chad, and Libya have agreed the plan. The UN suggests there could be 400 years worth of water available through this aquifer.

Exercises

1. Compare the areas that are predicted to have water stress in 2025 (Figure 4.8) with those that experienced water stress in 1999.
2. Explain why poor people often pay more for their water than rich people.
3. Evaluate the use of drip irrigation.
4. For urban areas, examine the range of ways in which water use can be made more sustainable. What is the percentage of water that is used for agriculture:
   - **a.** globally?
   - **b.** in LEDCs?
   - **c.** in MEDCs?
5. Explain how one technical, one managerial, one institutional and one agronomic method may help improve irrigation water proficiency.
6. Outline the range of low cost irrigation methods available to small farmers

   Look at the Case study: 'Water and conflict in the Nile Basin', and answer the following questions.
   - **a.** Which three countries have the largest populations in the Nile Basin?
   - **b.** Which of the countries in Table 4.12 has the highest population growth rate?
   - **c.** Comment on the variations in water footprint between the countries. NB Ignore the data for South Sudan.
   - **d.** Plot a scattergraph to show the relationship between PPP (US$) and water footprint. Comment on the result you have produced.
   - **e.** What are the implications of population growth and poverty in the Nile Basin for the future use of water resources.
   - **f.** Suggest reasons why conflict may develop between different countries in the Nile Basin over the use of water.

Big questions

Having read this section, you can now discuss the following big questions:

- What strengths and weaknesses of the systems approach and the use of models have been revealed through this topic?
- To what extent have the solutions emerging from this topic been directed at *preventing* environmental impacts, *limiting* the extent of the environmental impacts, or *restoring* systems in which environmental impacts have already occurred?
- How are the issues addressed in this topic of relevance to sustainability or sustainable development?
- In what ways might the solutions explored in this topic alter your predictions for the state of human societies and the biosphere some decades from now?

Points you may want to consider in your discussions:

- How does a systems approach help in our understanding of unequal access to water resources?
- To what extent are there solutions for increasing greater access to freshwater resources?
- Outline the opportunities and barriers to managing freshwater resources sustainably.
- Suggest how, and why, access to freshwater resources is likely to change in the future.